A SYSTEM AND METHOD FOR DETECTING SIGNAL ARTIFACTS

The present invention relates to a system and method for detecting signal artifacts, in particular, to system and a method used with a patient monitoring apparatus that adapts

5   to a patient's condition and distinguishes between clinically-significant changes in the patient's state verse clinically-insignificant changes.

One common problem associated with the use of measurement instruments is erroneous measurements that result from the introduction of an artifact signal into the event signal of interest. Typically, a measurement instrument detects one or more

10   measured signals each comprised of the event signal of interest along with some level of artifact related to one or more non-event signals. The resulting measured signals can become significantly corrupted such that they should not be relied upon as an accurate representation of the event signal. Artifacts that corrupt the event signals can result from mechanical disturbances of sensors, electromagnetic interference, etc. As will be

15   appreciated by those of skill in the art, the nature of the artifact signals will vary depending on the nature of the measuring instrument and the environmental conditions under which the measurements are taken.

One area in which the presence of artifact signals presents a potentially life-threatening problem is in the area of medical diagnostics and instrumentation. The

20   appearance of a non-event signal in a patient monitoring device could result in a clinician making an incorrect decision with respect to a patient's treatment, or, for devices that use algorithms to make decisions, could result in the device itself making an incorrect assessment of the patient's condition.

In conventional patient monitoring systems, alarms are typically generated on

25   crossing a limit or threshold in a signal being monitored, e.g., heart rate. While the threshold method is useful in determining physiological limits of variation of a parameter, it is not always the best method of event detection. The information that the clinician usually wants is the detection of relevant abnormalities or changes in a patient's condition. This is not easily reflected in a value crossing a limit, but rather by the simultaneous

30   evolution of different parameters.

In practice, wide variations in a given parameter can be observed without any major alteration of the physiological function of a patient. Many of these fluctuations

cause a false alarm in conventional patient monitoring systems. While the parameter being monitored did cross the limit, the alarm has no clinical significance. In such a case, for example, no major event is related to the worsening of the patient's status. As a result of this, many alarms in conventional patient monitoring systems are usually perceived as

5   unhelpful by medical staff because of the high incidence of false alarms, i.e., alarms with no clinical significance.

As discussed above, conventional alarm techniques generate an alarm signal based on setting a threshold. For every parameter, the trigger of the alarm is set off immediately if its value reaches the limit or in some cases when its value has been beyond the limit for

10   a given time. On the same patient monitoring system, when the values of several parameters are beyond the limit, an audible signal may be triggered on the first parameter that reached the alarm threshold; alternatively there can be a hierarchy of alarms. Generally, in all cases, it is necessary to set the threshold alarm limit.

Conventional patient monitoring systems provide for the setting of an alarm on

15   most physiological data. In some cases, more than 40 alarm sources can be active, e.g., ventilation data, electrocardiogram, arterial pressure and pulse oximetry for a patient undergoing mechanical ventilation. In addition, perfusion pumps, nutrition pumps, automatic syringes and dialysis systems may also generate alarms.

False alarms may have several adverse consequences. A constant stream of false

20   alarms may result in nurses delaying their intervention or trying to recognize life-threatening alarms by sound only. This practice may have severe consequences when the patient's condition is deteriorating.

What is needed is an improved method for detecting the presence and significance of artifact signals that may corrupt an event signal so that false alarms can be minimized.

25   The present invention is directed to a method and system for detecting signal artifacts, in particular, to system and a method used with a patient monitoring apparatus that adapts to a patient's condition and distinguishes between clinically-significant changes in the patient's state verse clinically-insignificant changes

One embodiment of the present invention is directed to a method for detecting a

30   signal artifact in an event signal. The method including the steps of receiving at least two event signals, determining a global correlation for the at least two event signal over a first period of time, determining a local corrlation for the at least two event signals over a

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second period of time which is shorter than the first period of time, determining a deviation between a local correlation vector and a global correlation vector, determining an average deviation from the deviation, and determining whether an artifact was detected in one of the at least two event signals based upon the average deviation.

5   Another embodiment of the present invention is directed to a device including a controller, a memory coupled to the controller, and an input interface arranged to received at least two event signals. The controller is arranged to determine a global correlation for the at least two event signal over a first period of time, determine a local corrlation for the at least two event signals over a second period of time which is shorter than the first

10   period of time, determine a deviation between a local correlation vector and a global correlation vector, and determine an average deviation from the deviation and determine whether an artifact was detected in one of the at least two event signals.

        more complete understanding of the method and apparatus of the present invention is available by reference to the following detailed description when taken in

15   conjunction with the accompanying drawings wherein:

        FIG. 1 depicts a diagram of a monitoring system according to an embodiment of the present invention;

        FIG. 2 is a flow chart illustrating a method in accordance with one aspect of the present invention; and

20   FIG. 3 is a graph showing the deviation away of local correlation vs. the global correlation when monitoring an Arterial blood pressure signal (ABP) for a patient with a clinical case of pulmonary edema.

        In the following description, for purposes of explanation rather than limitation, specific details are set forth such as the particular architecture, interfaces, techniques, etc.,

25   in order to provide a thorough understanding of the present invention. For purposes of simplicity and clarity, detailed descriptions of well-known devices, circuits, and methods are omitted so as not to obscure the description of the present invention with unnecessary detail.

        FIG. 1 is a block diagram showing a system 10 according to one aspect of the

30   present invention. One or more potentially corrupted event signals 11 are provided to a measurement device 20. The measurement device 20 includes a controller 21. The

system 10 may also include a plurality of sensors 30 that obtain the event signals 11 and provide event signals 11 to the measurement system 20.

Several specific implementations of the system 10 are contemplated. For example, in one specific embodiment, the system 10 is a patient monitoring system capable of monitoring a plurality of patient parameters. Patient parameters include, but are not limited to, ECG, EEG, pulse, temperature, or any other biological activity. These patient parameters would be the event signals 11 of interest. In another more specific implementation, the system 10 is a defibrillator capable of measuring an ECG. In that instance, the ECG would be the event signal 11 of interest.

In another implementation, the measurement device 20 is part of a server in a client-servant network, e.g., the Internet.

As will be appreciated by those of skill in the art, the present invention is not limited to medical applications. The artifact detection techniques of the present invention can be used to detect artifact from any measured input signal source. For example, equipment that is used to measure ocean temperature, seismic activity, etc. can be set-up so that additional input signals are provided for signal processing and correlation with the signal of interest in order to determine whether the signal of interest has been corrupted with artifact. In addition, aspects of the present invention can be applied to systems that measure multiple event signals, wherein each event signal would employ this artifact detection method.

For purposes of illustration, an artifact detection technique in accordance with one embodiment of the present invention is described below in conjunction with patient monitoring equipment.

In this embodiment, a plurality of patient event signals 11 (s_1, s_2, s_3, ..., s_n) are monitored. In this embodiment, the measurement device 20 is a patent monitoring system such as those used in an intensive care unit of a hospital. As one or more of the sensors 30 are connected to a patient, the event signals 11 start flowing into the measurement device 20. In this embodiment, the measurement device includes a memory 21 for recording the input event signals 11.

For each of the plurality of patient event signals 11 an indicator for the presence of artifacts in each is needed. Fig. 2 is a flow chart showing the steps of obtaining such an indicator. In a preferred embodiment, the steps shown in Fig. 2 are implemented by

computer readable code executed by a data processing apparatus or controller 21. The code may be stored in a memory (e.g., memory 22) within the data processing apparatus or read/downloaded from a memory medium such as a CD-ROM or floppy disk. In other embodiments, hardware circuitry may be used in place of, or in combination with,

5   software instructions.

In step 100, a history of event signals 11 is gathered and/or received. For example, in the patient monitoring system situation, event signals 11 are received for each patient to be monitored. This history may be a few minutes and may expand over a few days. Preferably, this history is at least ten minutes. The history data can be fixed for a

10   specific period of time or be updated at predetermined times, every ten minutes, every hour, etc. For example, in the case of the patient monitoring system, the history for particular patient may be fixed as the first hour the patient is being monitored.

In the case of patient monitoring systems, samples are typically collected at a rate of ~ 125 samples/second. Other sample rates, however, may also be used. Accordingly,

15   in a matter of few minutes to a few hours of time T , a large number of samples (history) for each of the monitored event signals 11 (s_1, s_2, s_3, ..., s_n) are collected.

In step 110, a cross correlation, "r", among these recorded event signals 11 is determined. The cross correlation provide an overall correlation matrix, r_{global}, as shown in equation

20   (1) below. This overall correlation matrix provides a norm or steady state for a particular patient.

$$r_{Global} = \begin{pmatrix} r_{11} & \cdots & r_{1n} \\ \vdots & & \vdots \\ r_{n1} & \cdots & r_{nn} \end{pmatrix}_{Global} \tag{1}$$

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In step 120, a local correlation matrix is calculated over shorter periods of time is calculated. The short-term period of time may be a few seconds to a few minutes (typically 12 seconds). In the present patient monitoring example, a short-term period of 12 seconds yields 1500 samples per signal. This results in a local correlation matrix, as

30   shown in equation (2) below.

$$r_{Local_i} = \begin{pmatrix} r_{11} & \cdots & r_{1n} \\ \vdots & & \vdots \\ r_{n1} & \cdots & r_{nn} \end{pmatrix}_{Local_i} \tag{2}$$

Where the number of these local correlation matrixes equals N

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$$N = \frac{T(in\ seconds)}{12\ (Number\ of\ seconds\ for\ local\ correlation\ calculation)} \tag{3}$$

In step 130, the deviation between the local correlation matrix feature vector and the global correlation matrix is determined. This is an indication of the current patient

10 status and its variability.

This difference is defined as

$$\vec{D}_i = r_{Global} - r_{Local_i} \tag{4}$$

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The root mean square of this deviation vector is an indicator of the absolute value for the deviation between the current status and the global information.

$$D_i = \left| r_{Global} - r_{Local_i} \right| \tag{5}$$

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In step 140, the average deviation is determined. This is an indicator of the normal/acceptable instantaneous deviation of the patient's recorded information vs. his/her overall recorded history.

25 $$D_{average} = \frac{1}{N} \sum_{i=1}^{N} D_i \tag{6}$$

When any of the monitored event signals 11 suffer from the presence of an artifact, its local correlation matrix (equation 2) varies largely from the global correlation matrix (equation 1) and the associating deviation (equation 5) varies largely from the average deviation (between local and global correlation matrix as defined in equation 6).

5   When an alarm is present with a large deviation away from $D_{average}$, this is an indication that the normal correlation pattern has been locally violated and the alarm present is of low credibility and most likely is a false alarm. Generally a large deviation is in the range of 10%. However, the exact range for a "large" deviation can be adjusted in accordance with known fluctuations in particular signals and/or normally observes 10   ranges in such event signals.

In step 150, if the deviation is less than and/or equal to a predetermined threshold range an alarm indication may be provided.

Fig. 3 is a graph showing the deviation away of the local correlation vs. the global correlation when monitoring an Arterial blood pressure signal (ABP) for a patient with a 15   clinical case of pulmonary edema. The first and second alarms have a low deviation away from the average deviation (the red dashed line), while the third and forth alarms have a significantly high deviation. This indicates that the first and second alarms are TRUE alarms while the third and fourth alarms are FALSE alarms.

While the preferred embodiments of the present invention have been illustrated 20   and described, it will be understood by those skilled in the art that various changes and modifications may be made and equivalents may be substituted for elements thereof without departing from the true scope of the present invention. In addition, many modifications may be made to adapt to a particular situation and the teaching of the present invention without departing from the central scope. Therefore, it is intended that 25   the present invention not be limited to the particular embodiment disclosed as the best mode contemplated for carrying out the present invention, but that the present invention include all embodiments falling within the scope of the appended claims.